Synopsis

Forests provide a variety of useful products, such as food, medicine, clothing, furniture, etc., for humans as well as other living organisms. Research and policy widely acknowledge the reliance of rural and urban communities worldwide on forests for subsistence, health, and livelihoods. Non-timber forest products (NTFP) include all plant and animal derivatives collected from forests. Among the plant parts harvested, root-harvested species and climbers among life forms are rarely attempted for research. While there are results from various NTFPs exhibiting both positive and negative consequences in response to harvest, The conditions are lethal based on which plant part is harvested, especially the roots, tubers, bark, whole plant, etc. *Decalepis hamiltonii* is a woody climber endemic to Karnataka, Kerala, Tamil Nadu, Andhra Pradesh, and Telangana states and distributed in scrub and dry deciduous forests. The thick and stout tubers of this plant are largely collected from the wild by tribals as it is a NTFP and is preferred to be used as a substitute for *Hemidesmus indicus.* The aromatic roots pose a cocktail of medicinal properties and are of multiple uses, most importantly as a source of vanilla. The presence of a flavour molecule in the roots of 2-Hydroxy-4-Methoxybenzaldehyde (2HMB) is an isomer of vanillin, and the root extracts are found to be 100-fold stronger in providing a vanilla flavour than the natural vanilla extract. The *D. hamiltonii* population is assessed as endangered due to overexploitation, destructive harvesting of roots, and habitat loss.

Apart from biotic and abiotic factors, anthropogenic activities have altered the natural habitats, with impacts on other species in that area. Savandurga Reserve Forest (SRF) harbours the *D. hamiltonii* population and also has a designated medicinal plant conservation area (MPCA) to save the gene pools of several medicinal plants, including *D. hamiltonii*. Though this species has been researched in all aspects and has always been under the radar of conservation and sustainable harvesting programmes in SRF, throughout the distribution range, the population has been facing root extraction. So far, there is no specific quantification of the density or size class of the D. *hamiltonii* population or attempts to know what the effect of root harvest is on its survival, yield, or reproductive status. The increasing demand for roots from the wild, coupled with the absence of any assessment of the population status or vital conditions, raises questions about its population status.

In the interest of finding the population status and size class distribution, I grided the area using geospatial tools, used the Normalised Difference Vegetation Index (NDVI) to categorise the habitats, and used digital elevation models to derive features like elevation, slope, aspect, and hill shade illumination. I laid 240 plots of 5 x 5 m across 24 grids in SRF and enumerated a total of 405 plants and 392 other life forms found associated with *D. hamiltonii* from the plots. All kinds of disturbances (groat grazing, fire, cattle, root harvest, cutting reproductive stems) observed in each grid were recorded and the density was compared across habitat types and harvesting regimes. I found that the population of *D. hamiltonii* individuals comprised largely adults (188) than seedlings (154) and the least number of saplings (65) individuals. Overall estimated mean density/ha of *D. hamiltonii* in SRF is (mean ±S.D.: 675 ± 455 stems/ha). Estimated density for adults (mean ±S.D.: 313 ± 210 stems/ha, N = 24), seedlings (mean ±S.D.: 304 ± 232 stems/ha, N = 20), and saplings (mean ±S.D.: 153 ± 144 stems/ha, N = 17). The highest number of 52 stems were found in the sample plots laid in the MPCA (Grid No. 25), with a mean ±S.D. of 5.2 ± 2.66/25 m^2, indicating a clear benefit of the restriction implemented by the management. Though the population represented an inverted "J" curve, there is a noticeable reduction in densities of the size class (3–6 cm), *i.e.*, the saplings, indicating an unstable population structure and a forewarning.

Dense vegetation had the fewest but largest individuals (above 20 cm. gbh to 30 cm. gbh) and new recruits only in the gaps compared to other habitats. Rocky and mixed vegetation had maximum density as they are open areas supporting seed germination and establishment. Adult *D. hamiltonii* distribution was determined solely by harvesting (78% variation explained) and was abundant in both high- and low-harvested areas. More individuals were found in open areas, gaps, and disturbed sites, as they are climbers and have an affinity for light. Environment variables such as NDVI (2.09%) and altitude (18.72%) were positively correlated with sapling abundance and explained 58% of the variation. The aspect variable determined seedling abundance, as it negatively correlated with the aspect variable, indicating that densities increase as one travels from north to south in SRF. However, the directional variable only explained 4.44% of the variation. *D. hamiltonii* grows luxuriously in dense forests and loamy soil, provided they are not harvested. Whereas rocky and mixed vegetation support the establishment of the population and ensure long-term support, as it is not easy to harvest roots from the rocks. Intense root harvesting and drying of the material were observed in areas that were out of sight and too interior in the forest. Goat grazing and feeding on the leaves of this

plant was evident, and goat herders pulling down the fruiting branches to feed the goats added to the intensity of the disturbance.

A clear picture of the associated species richness, community composition, spatial patterns, and interactions is required for effective conservation planning or even to cultivate and domesticate the plant. Being a woody climber, *D. hamiltonii* relies on various life forms for support at various stages of growth before reaching the canopy. From the enumerated 392 plant species, 77 species are trees, 46 species of shrubs, 66 species of climbers, 158 species of herbs, 44 species of grasses, and bamboo. The novelty of this study is that it covers the entire landscape and includes all life forms, from grasses to trees, as they are connected with *D. hamiltonii* both aboveground and with the roots belowground. The rate of species accumulation in this study was much higher for herbs and trees than for climbers and shrubs, indicating the possibility of discovering more species. Herbs and grasses were highly diverse in the mixed vegetation, followed by rocky outcrops, while dense vegetation was the least diverse. Alpha diversity was similar across habitat types and indicated vegetation homogenization within the landscape. Higher tree densities predicted lower *D. hamiltonii* densities, indicating that higher *D. hamiltonii* densities are mostly found in open canopies. The beta diversity of life indicated 54 to 70% similarities, i.e., more than half of the species are common across habitats. Only the "sites," or geographical locations, of the sampled plots explained the variations that indicated spatial autocorrelations. At multiple spatial scales ranging from 500 m to 7.5 km, both univariate (species richness and densities) and multivariate (species compositions) data were spatially correlated. As a result, plant life forms in SRF are homogenised at various spatial scales, but the same species composition packing in numbers varies, i.e., species associated with each microhabitat differ. *Albizia amara, Wrightia tinctoria, Euphorbia antiquorum,* as well as armed species like *Pterolobium hexapetalum, Acacia pennata, Canthium coromandelicum, Catunaregam spinosa, Barleria prionitis,* and *Flueggea leucopyrus,* support the population from seed germination to the adult stage. The rocky habitat is a major advantage as they serve as “safe” or “refuge” sites, playing a larger role in the sustenance of the population. Root harvesting of *D. hamiltonii* equally destroys the neighbouring lifeforms and provides space for Lantana species growth.

After understanding the population status and the associated species diversity, I wanted to know how the species responds to root harvesting experiments to understand how they survive, reproduce, and grow new roots. I conducted root harvesting treatments (HT) of two types, *i.e.*, 50% HT and 80% HT root removal, on 62 samples (31 plants for each treatment) and studied their consequences for a period of 2 years. Measurements of roots were collected before harvest on root size, fresh weight, girth, length, morphology, position, depth, and distribution in the soil. This study provides new information on the roots of a climber species based on excavations from the wild, which are rarely attempted. Leaves and root samples were also collected before and after harvest to check whether there were any changes in the responses. Unfortunately, the samples could not be retained beyond 2 years due to constant human interference (i.e., root harvesting). The main findings are: The root harvest has a negative impact on the population by delaying the growth and reproductive progress of individuals at various stages, indicating more time is required for root regeneration. Larger stems survived the odds, and younger stems died as they could not withstand 80% HT. Whereas the 50% HT group outperformed the 80% HT group in four ways: a greater number of survivors, continued reproduction to the following year, a higher percentage of root yield, and a greater number of new roots. Carbon% and nitrogen% in the leaves and roots from both treatments were significantly higher after harvest compared to the preharvest stage. Though the leaves exhibited an increase in nitrogen, there was a significant decrease in carbon after harvest, indicating a shortage of resources in the above-ground tissues as the requirement for new leaf development is required for survival and continuation of fruiting in reproductive individuals. As per the local harvester's assumption, regression model results for root weight predicted that basal girth determines root yield, i.e., plant age (stem size or girth) predicts root yield; the older the plant, the larger the yield. The maximum root girth observed from a large stem of *D. hamiltonii* measuring 28 cm gbh was the root girth of 15 cm before harvest, which resulted in 11 cm girth after harvest.

Reproduction: In both treatments, the number of fruits, seeds, and seed germination was reduced in the T2 stage (after harvest), but this reduction was very large when compared to the unharvested control group. The harvest treatments resulted in germination rates of 5.3% and 5.9%, respectively, which is very low in comparison to the unharvested (control group) results, which showed 72.3%, indicating a significant negative impact on population recruitment due to root harvest. Delaying the saplings growth progress to the adult stage, halting the fruiting of previously reproducing individuals, and invoking fruiting in individuals that were previously

not fruiting in the T1 stage (before harvest) are the types of mixed responses observed in both treatment groups. Root harvesting resulted in fewer fruits, seed set, and poor seed germination compared to the control population in both treatments, which is a reproductive bottleneck for the population. Roots are the storage organs of a plant and have a larger long-term role in the functioning and structural support of the plant. They are not like other plant parts such as leaves, flowers, fruits, seeds, etc., which are shed annually or seasonally.

Invariably, whether it is 50% or 80% HT, the results hold true for first-time root harvest only. Both treatments are not suitable for consecutive harvests of the same plant or for the same area, as the plants require a sufficient recovery period for root growth. Since my study is based on only one or two years of responses, it provides a wealth of new information and evidence that is rarely studied. But the limitation is that the results and responses are based on a short period, and further dynamics on growth, yield, and reproduction are not captured, unfortunately. This situation necessitates long-term monitoring and tracking of the population from seedling to sapling and reproductive phases based on size-dependent factors to understand the ecological responses. Varying levels of harvesting intensity need to be tested based on the size of the individual to understand the root recovery period, with an appropriate spatial planning of an area-wise rotation period before prescribing sustainable harvesting methods.

Strict regulation for the MPCA as well as the adjacent area, followed by restoration in degraded and highly harvested peripheral grids. Encouraging local and large-scale cultivation, domestication, capacity building, and awareness among the stakeholders are essential. At the moment, the action required is to protect the remaining population from anthropogenic pressure and provide sufficient time to recover. Citizen science cooperation by reporting harvesting events will help the Forest Department take action. Mitigation here is to primarily remove or control the mentioned human harvesting pressure and goat grazing/herders. Equal importance is required for the natural habitat, which provides natural protection, and the associated species, which play a role in the sustenance of the population. Anthropogenic features may act as both barriers and enablers for the landscape; developing effective management schemes for protecting and maintaining the landscape is key to the conservation planning of such species. SRF needs protection of the D. *hamiltonii* population without undermining the role of the associated species diversity and the forest habitat, which are naturally fulfilling the conservation goal.

D. hamiltonii individual with the stem measuring 22 cm gbh was selected for 80% harvest treatment The maximum root length was 2.5m to 3.5m, maximum root girth was 13 cm. All the experiments conducted in the field was with the support of the Forest Department staff (watchers Doddaya & Kambayya)